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ABSTRACT

Two articles in this newsletter describe programs related to the use of investigative laboratories in college biology; one reports on student reactions to such laboratories; and two articles describe student directed activities concerned with environmental factors. Comments on the changing role of biology in the 70's, and its implication for college biology instruction, a bibliography of 42 items concerning grading practices, and a discussion of the relevance of a core curriculum containing minimum subject matter required of all biology students in the face of rapidly expanding research data, are included in this penultimate edition of the newsletter. (AL)

CUEBS

COMMISSION ON UNDERGRADUATE EDUCATION IN THE BIOLOGICAL SCIENCES

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NEARING THE FINISH LINE

This is the next to last issue of **CUEBS News**. *A report on the terminal activities of the Commission and disposition of its effects will appear in a final issue which will be mailed sometime in the fall. Formal operations will cease as of July 30, but there will be a phase-out period through December to allow for publication of several studies now nearing completion and for the distribution of materials already published. The office address will remain the same during this phase-out period.*

THE EDITOR

THE CHANGING ROLE OF BIOLOGY IN THE 70's

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The time is late for beginning a restructuring of upper level courses and programs in all areas of liberal arts education that should have been accomplished in the Sixties and earlier. Those individuals who must guide our species through the close of this century and into the equally critical years of the next have the major portion of their education ahead of them. By acting immediately in responding to last minute challenge, individuals directing centers of advanced learning can yet achieve far-reaching benefits from sound, though what may be somewhat extreme, undergraduate and graduate level curriculum reform.

The words curriculum reform have a familiar ring. They call to mind long, often traumatic staff sessions that have occurred periodically during the careers of academicians; always at the expense of other duties. Change of minor significance has come about by this means, but ever so slowly in our tradition-bound educational sphere of the liberal arts college in which countless factors inhibit and in which recycled policies appear to pre-empt innovation. Fortunately we continue in the attempt to educate within an operational framework which claims such objectives as "breadth of knowledge" and "critical thinking" most worthy and necessary.

It is the opinion of some, however, that a third goal should be added to these objectives in those undergraduate programs intending to afford students more than an educational luxury called "culture." They recommend a specialized training segment of instruction that could provide a technical-administrative "know-how," which would combine individual aptitude and interest with a society need; to provide a "package deal," as it were, ready for almost instant implementation following full accreditation of the individual. It would be the educator's responsibility to recognize and anticipate needed areas of society and to provide flexible programs in all dimensions to fit these needs. Such programming might indeed be accomplished realistically without sacrificing the benefits of a liberal arts education for all-out vocationalism.

That which for so long has been a fashionable and workable philosophy underlying the liberal arts educational system, it might be argued, should not be altered in such an "unscholarly" manner. Resistance from within the system continues in the form of such phrases as "we cannot afford to cheapen the degree, . . . to lower standards, . . . to educate the masses." If this stand were tenable at any time, perhaps it can no longer be so regarded.

While we all know that "chance favors the prepared mind," we also know that there always have been those graduates who never quite find a suitable slot in which to apply their "breadth of understanding" profitably to themselves and to

Based on an address given at the Louisiana Conference on Biological Education, Nicholls State University, Thibodeaux, Louisiana, March 5, 1971.

society. A trend allowing relaxotion of residency rules for off-compus job experience, alreody in effect ot some colleges and universities, may assist students with curriculum planning and more meaningful job identification. If such innovation can be managed by admissions and records offices, perhaps courses—even curricula—could be conceived at the department level in which content might be integrated with job experience. Cooperation to this extent between college and "outside" agency has long been sought unilaterally. Apart from student benefit, the odvantage gained by the hiring organizotion might well be reflected back to the college in the form of program support.

Thinking along related lines, it becomes fairly obvious that the ever-present low marketable potential of the liberal arts degree holder will decline even further in direct proportion to the overall increase in "unskilled" degree awardees. Rising college enrollments are being absorbed by expanding state university systems and by an increasing number of private colleges as these proliferate. Fluctuations in this pattern are to be expected correspondingly with economic fluctuations; however, I think that a long term rise is predictable. To what extent the women's liberation movement will compound the problem is not predictable. In any event, there is an ever increasing resource of tremendous work placement potential going unfulfilled for want of what might be occomplished through moderate modification, namely, toward the cultivation of technical-administrative know-how, in higher education.

There is yet another area wherein we find institutions of higher learning nonadaptable. The apparently low marketable potential of the Ph.D. degree holder, ot the present time at least, should be reason enough for reassessment of all matters pertaining to graduate instruction in liberal arts programs. It is my opinion that not all students of merit need pursue the customary graduate program route toward an advanced degree. Most certainly other outlets for specialization are known or could be developed, here again, as at the undergraduate level, integrating course content and research activity with the needs of "outside" agencies. Of course such programming would have to be superimposed on troditional or "equivalent" requirements if an advanced degree is sought. Otherwise detailed transcript data might suffice as certification in lieu of a degree.

Biological sciences personnel in particular cannot afford to ignore the need of applying thorough and open-minded self-study at all higher education levels. Corrective measures adapted to the times and to specific needs must be selected and implemented with wisdom, but boldly, in all formal courses of instruction which relate in any way to man and his environment, at all undergraduate and graduate levels, at all degree-granting institutions, and at all cost. However, instructional objectives and instructional methodology both require reassessment toward this end. The urgency for such action must be recognized and responsibility accepted by every teacher, administrator, and funding organization involved.

Consider first how we foil to provide encouragement and specialized preparation for students concentrating in the naturol ond physical sciences who might fill critically needed positions in the areas of technical ossistance to professionol programs. Such educated and trained personnel deployed to support medical and dental programs and to support research teams engaged in both applied and non-opplied research, could perform an infinite number und variety of responsible services.

Consider the rationale behind this recommendation for increased specialization in undergraduate course design and educational programming without sacrificing that breadth offorded the student by complementary liberal arts studies. Remember that not every student concentrating in the biological sciences requires routing through courses designed for the ultimate Ph.D., M.D., and D.D.S. degree candidote. Many students by inclination ond according to aptitude who now qualify for the B.S. degree as their sole educational objective find themselves ill-prepared in applying this preprofessional substance elsewhere thon toword graduate study. Be reminded also that the Ph.D. himself has an extremely limited number and variety of positions open to him at the present time. Thot this "tight job" situation will change in the near future seems unlikely in that funding agencies have withdrawn their support heavily from Ph.D. progroms, both in education and research, favoring the support of innovative courses and instructional programs as these are conceived. This is especially the case in newly-sponsored training progroms related to health care and teacher education.

The point of all this is that consideration should be given to the advisability of tailoring a sufficient number of courses in the biological sciences to fit societal needs and the variety of student goals; certainly incorporating into these courses the type of instruction that will afford substantiol guidelines to the student for the development of value judgments based on the concept of survival. In this context, it should be mentioned that the removal of administrative barriers to the development of interdisciplinary courses for senior year presentation, where these occur, must somehow be achieved.

Regarding the matter of selecting those methods most appropriate to the task of presenting an instructional package of quality designed for preporing the graduate for a more effective role in society, it should be obvious that both "old" and "new" techniques warront evaluation. CUEBS has reported on these techniques at length. All of them have merit if applied to convey information effectively at a rate capable of accommodating and challenging a reasonable spectrum of student aptitudes. Any course, however, might best include group instruction combined with those methods which involve the student individually in a learning experience which he can program at will.

It is also my opinion that selection of the person to teach the subject matter and to direct learning is the most important consideration to be made in the process of course restructuring. Whether or not the course achieves the necessary appeal will depend substantially on the personal and academic qualifications of the individual chosen as well as on those methods selected to fit the objectives of the course precisely.

Maximum student enlightenment and enthusiasm stem from direct contact with a knowledgeable, capable, and enthusiastic human being, the teacher. Without him the lecture portion, the teaching module, the A-T approach, programmed instruction, or whatever the method applied, will meet with minimal success. Innovative techniques simply cannot function alone to impart "knowledge with wisdom."

Many of the opinions and predictions presented above constitute radicalism according to the most fundamental meaning of that word; ". . . going to the source or the root of . . ." a question. In this instance I wish to call attention to an extremely complex and urgent matter from a stance within our relatively static system. Sacred procedures have been challenged and extreme alternatives are proposed because, on the one hand, I am greatly alarmed (along with others) over our species dilemma. Among other corrective measures a radical change in educational policies and methods can pull us through.

Obvious "pressure" outside our system apparently will allow us little choice in this decision. The Secretary of Health, Education and Welfare has identified curriculum reform as a major task ahead. Representatives of the Office of Education, NSF, and NIH, each in their own way, have clearly indicated that reform is intended and will be achieved, preferably with the cooperation of our colleges and universities. To be convinced that this is a very real trend one need only observe which programs at any level are being funded. I propose that change be initiated to the extent possible from within the system, by our hand.

A STUDENT DIRECTED COURSE ON BIOLOGICAL PROBLEMS IN CONTEMPORARY SOCIETY

Joan G. Creager
CUEBS Staff Biologist

> natural beauty vs. polluted waste
> is there a natural beauty
> found
> in such a city, complex
> and mad with polluted waste
> stopping in the gutters of concrete
> climbing the wall of evolving trash—
> waste washing past mine eyes,
> in collected aggravation
> with the natural waters,
> waters cleansing a child of his miseries;
> waters crashing,
> and tumbling to locking and intertwining breaks of waves;
> waters dropping joyously on nature's friends,
> the trees of life.
> the contrast of this sort—
> wastes our land—bleaches the natural color collage,
> and strips our minds of beauty
> flowing freely amidst the universal land.

Ayn Frances Strattner was inspired to write that poem as a part of her activities in the course entitled Biological Problems in Contemporary Society. The course is a one-quarter, three credit-hour course offered at the freshman level at Northern Virginia Community College. Many of the students have had a year of natural or social science. However, the course has also been offered at a local high school where students have the option of taking the course for either high school or college credit. A reading list replaces the traditional textbook.

Very early in the initial planning of this course, it became apparent that, even if one were motivated to do so, it would be impossible to include all of the socially relevant content of biology in a one-quarter course. Instead, I decided to experiment with a student-directed course. My rationale for a student-directed course is threefold. First, much of the content of a course is obsolete by the end of the course. This is especially true of a course focused on contemporary problems. However, content, as factual information, becomes a necessary part of any problem a student chooses to tackle. Second, the future use of a course such as this one depends primarily on students developing their abilities to define and study problems of their own choosing. If we look carefully at our own experience, it is easy to see that we learn most readily things that we need to know. Students choose problems about which they want to know more. This is a strong motivating factor so that students enthusiastically engage in researching problems and proposing possible solutions. In this course, students learn how to tackle a problem. They can use the skills developed to solve problems they encounter in the future. And, third, each student should have maximum opportunity to engage in independent study at his own rate and according to his own interests. In a student-directed course, any individual can enjoy this opportunity. Often, students infect each other with interest and enthusiasm for particular topics. Peer interactions cause students to broaden their view of what is relevant.

The four basic objectives of the course are defined by the instructor at the beginning of the course as follows: (1) recognition of problems in modern society which are related to biology; (2) investigation of selected problems; (3) introduction of possible solutions; and (4) development of ways to implement possible solutions.

To help students accomplish these objectives and to encourage student interactions, discussion exercises and simulated situations are used. One discussion exercise is called "The Goldfish Bowl" which was prepared by the National Training Laboratories. An inner circle of four to six students discuss a designated topic, while an outer circle of four to six students act as observers. The observers note which students participate most, which least, who talks to whom, and, if one member shuts out or encourages another member to

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express an opinion. In discussing the observations made by those in the outer circle, students recognize which types of behavior facilitate productive discussions and which hinder them. Ideally, participants in the inner and outer circles exchange positions and the exercise is repeated to allow each student to be involved in both discussion and observation.

In a simulated situation, one might have the students pretend that they are o committee of citizens concerned about their community who oppose the construction of a new sewage disposal plant. Or perhaps these concerned citizens oppose a bill to abolish tax deductions for more than two dependents under 18 years of age. The situation might be a Congressional Committee studying a proposed bill. Students are assigned roles to be played in the simulated situation. One student might be the president of the citizens' associotion while other students might play the manager of the present sewage disposal plant, the parent who is concerned with the health of children who might play in the polluted creek, or the overburdened taxpayer who says, "Keep your kids out of the creek and don't raise my taxes." The purposes of such simulated situations are to help students envision their future roles in society, to develop leadership potential, and to encourage them to become well informed about contemporary problems.

Beyond these activities, my role has been to serve as resource director: to suggest information sources, to arronge for equipment and facilities, and to generally encourage students in their chosen activities.

What have the students actually done when given the opportunity to decide what they would like to do? There are a few, of course, who do very little. But then it is quite possible for students in more traditional courses to do very little. There are also a few students who will do whatever they are told and do it very well. Some of these students are ill-at-ease in an unstructured, student-directed course, possibly because they are not being crammed with predigested information and feel that they are not learning anything.

The course was offered for the first time in the fall quarter of 1970. The class of about ten students met for 3 hours one evening per week. This group turned out to be a conscientious student activist group. I had them do the "Goldfish" exercise and assigned the topic, "What do you expect to get out of this course." The main conclusion of the discussion was that they did not want to talk about problems, they wanted to do something about them. Problems that emerged from future class sessions were: (1) the lack of public awareness about environmental issues; (2) the need to encourage consumers to use their buying power to minimize pollution; and (3) the need to draw the attention of elected officiols to current problems.

To increase public awareness about environmental issues, the students designed a bumper sticker which said, "Pollution grows, nature dies." They prepared a series of color slides depicting various aspects of pollution. This presentation was accompanied by music and narration. While the actual presentation lacked something in public relations and logistics, the students became aware of some of the problems of creating concern within an apathetic student body.

To encourage consumers to use their buying power to minimize pollution, the students prepared a one-page shoppers' guide which gave pointers to shoppers about the types of containers most easily recycled into the economy. These were distributed with the bumper stickers at a shopping center one Saturday.

Since the course was offered during the heat of the congressional campaign, the students invited the incumbent congressman and his challenger to speak to the student body on environmental issues. The incumbent declined the invitation. The challenger came and spoke to a disappointingly small group. Obviously, this activity was less than successful in terms of participation by students and candidates; still it did demonstrate that students can gain the attention of political candidates. Since the election, several students have written letters to various elected officials about environmental issues.

The second class was small and was handled on a seminar-independent study basis. Each student selected two topics to research on his own and reported his findings to the class. One student arranged for a speaker to come to the compus to discuss the SST. Another is continuing his interest in environmental issues by working with the community groups. Perhaps the most ambitious student of any in the course is a lady who discovered so many topics she wanted to research that she has registered for an independent study course to continue her work.

A class of 25 high school students have just completed this course. They had the option of taking the course for high school or college credit. Over half wanted college credit. Three reports were required of those desiring college credit; two were required for high school credit. The breadth of topics selected and the depth of study made by many of these students was quite amazing to me. Examples of topics chosen are: alternatives to electric power, planned cities, sewage and solid waste disposal, the SST, organic gardening, land usage, health care, population control, conservation of local parklands, preservation of wilderness areas, and endangered species. The students were asked to propose solutions to the problems they investigated. Almost invariably and regardless of the problem, population control was mentioned among the possible solutions.

Every student was asked to do a self-evaluation as one of the requirements for the course. On the first part of the evaluation each student was to describe what he expected to accomplish in the course and what he had done or planned to do to accomplish his goals. Most of the students mentioned becoming better informed about contemporary problems in biology and learning to investigate a problem independently.

Students were also asked to estimate how much time they spent each week reading, interviewing people to gather information, and explaining to people the problems of the environment. The amount of reading varied from 2-12 hours. The time spent interviewing varied from none to 3 or 4 hours, depending on the nature of the topic being investigated. Some students who selected local problems were able to contact individuals who were quite willing to talk to them. A few made numerous phone calls without ever locating a source of information—only another number to call. About half the students spent time each week attempting to change people's attitudes about the environment. Students discussed these problems with classmates not enrolled in the course, neighbors, and parents. Many were appalled that their peers intend to have as many children as they desire despite the possible consequences. Several students felt that no matter how hard they tried they could not convince their parents that there is need to be concerned about environmental problems. Perhaps the relatively affluent suburban setting places greater value on convenience than on ecologically responsible behavior.

In responding to an item about the student's own attitude changes, most students indicated that they came into the course because they were concerned about such problems. After reading and studying the problems, many found their attitude shifting from "concerned" to "desperately concerned."

Students were asked to indicate what grade they thought they deserved and why. Responses ranged from "A" (because I have accomplished the goals I set for myself or because I have completed all the requirements) to "B" or "C" (because I have accomplished some of the goals I set but have not worked as hard as I should have or I've gotten out of the course what I wanted). Several commented that when dealing with the serious problems considered in this course, grades are relatively unimportant.

Several students suggested that in the future the class have the opportunity to hear guest speakers. More time for class discussion was also suggested by some students. I find myself in wholehearted agreement with the students. The courses could have been improved by having more speakers, and in the Washington area, if arrangements are made far enough in advance, a variety of speakers are available. To provide more time for class discussion, classes could be scheduled to meet for more than one discussion hour per week, as was the schedule for most of the classes. The thought was that if we had small groups of six to eight students who spent most of their time in independent study, one hour per week of discussion of their activities would be sufficient. As experience shows most of the students can easily prepare in a 2-week period a report with enough information to provide a basis for a 30-minute discussion.

This course has now been offered under a variety of circumstances—night school, day seminar at the college, and at a nearby high school. With this limited experience, there are several things I would like to try in future courses. First, some modularized, self-instructional materials on various aspects of contemporary problems in biology would be useful to provide students with easy access to basic information in their areas of interest. The reports of students in past courses would be helpful in preparing these modules. Second, a greater variety of simulated situations could be used to help students get a fairly realistic view of the complexity of biological problems in society today. And finally, it would be desirable to have several months to arrange for speakers, films, and other special events.

While these modifications would be likely to better serve the students who are challenged by student-directed courses, they may not be helpful to other students. Many students have difficulty operating in an atmosphere where one must decide what one wants to do and take the responsibility for doing it. The "do nothings" seem to lack motivation in a student-directed course; I suspect they may also lack it in a more traditional course. The "course conquerors," on the other hand, are highly motivated. Provided somebody tells them exactly what to do, they will do it and do it well. In short, the "do nothings" seem unable to take responsibility for their own learning and the "course conquerors" seem unable to decide what they, themselves, want to do.

To close on a more positive note, nine out of ten of the students in these classes were able to adjust to and thrive on the unstructured situation. They were enthusiastic about the opportunity to define their own goals and quite successful in disciplining themselves to complete the tasks they set for themselves.

FOSTERING INNOVATIONS

The dean of instruction at El Centro College (Dallas, Texas), C. H. Palmer, has instituted a mechanism by which innovation is really encouraged by the administration.

El Centro offers what is called "Special Studies" in each academic division. These represent an academic wild card for which prerequisites, content, and credit are determined by the instructor, the division chairman, and the dean. If a professor develops the idea for a new approach, he can teach it on a trial basis without having to go through the formal curriculum committee routine and without incorporating the course into the catalogue. Each course may be offered a maximum of twice under this system. If it proves to be viable, it can then be formalized; otherwise, the experiment is dropped.

The division chairman and dean act as a brake on senseless proposals, but they can encourage the kind of innovation which frequently is completely prevented by the usual review of prospective new courses. The instructors are also stimulated by this system to engage in more free-wheeling thinking.

Dean Palmer's image is further enhanced by his practice of keeping a budget item, $10,000 for this year, allocated to developing new courses and improving existing ones. This is used to bring in consultants, to send El Centro faculty to other campuses, and so on.

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THE ROLE OF THE LIBRARY IN AN INVESTIGATIVE LABORATORY

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Two main objectives for the investigative laboratory have been suggested (Holt, 1969). First, the investigative laboratory should provide an opportunity for the student to develop attitudes toward the utility, strengths, and limitations of the scientific approach. The second objective is to provide students with an oppartunity to see the nature of scientific activities. Implicit in these objectives is the idea that the investigative laboratory will allow the student to develop his own ideas through a student-directed investigative project.

If the overall objectives of the investigative laboratory are to be achieved, the student's experiments in an investigative laboratory should not be isolated from the use of the library. There are three basic functions which the library can perform in supporting these objectives.

First, an exploration of scientific literature will reveal certain aspects of the nature of science. By using the literature in relation to a problem-solving operation, the student is required to do library research and, more important, to evaluate the literature in order to develop his experimental program. This activity will show him both the careless, confused experiment and the tenuous results it produces, as well as the simple experiment and the reliable results it produces.

If the student does a significant amount of literature review, he will have an opportunity to see how a specific topic has developed. For example, in plant physiology a student working on environmental factors affecting growth would find through his search that early plant physiology consisted mainly of observations on the gross morphological differences that could be demonstrated through changing the intensity or amount of the factor being studied. The further development of this field, as revealed to the student through the literature, includes more precise measurements of the factors involved, and more recently, the investigations of the biochemical mechanisms of the mode of effect of the environmental factor. However, this point should not be overemphasized. The student is not likely to come to any significant understanding of the overall history of a field, although over the shorter period of the recent past he can see the development of his topic. Therefore he can appreciate the idea that science is not static.

The second and most practical reason for the students' use of the library in an investigative laboratory is the students' need to be informed. The beginning student obviously does not have the background that the experienced student has. This inexperience must be compensated for if the student is to have an adequate understanding of the field in which he is working and is able to ask the right questions in formulating his investigation. This does not mean that the library is a substitution for advanced training. Instead, it should serve as a reservoir of information which can be tapped whenever a student's subject background is not satisfactory for the problem he is trying to solve.

Third, and most important, through the use of the library the student learns the relationship between the prior art and an investigation. By reading current information, the student can choose for his topic the appropriate methods and techniques, which the instructor has already shown him, what experimental data is now accepted in the field, and what work needs further experimentation. The literature will also reveal the current conceptual framework with which the laboratory data either agree or disagree.

The role of the library and literature in the development of science can be demonstrated by having the student actually experience it during an investigation. He is to learn by doing—not by reading or talking about it.

The importance that library usage plays in reaching the objectives of the investigative laboratory means that effective use of the library is crucial. It is therefore essential that whenever an investigative laboratory is used a substantial component of library instruction be included. For this instruction to result in an effective program, it should have the following characteristics:

1. The faculty must be committed to having students learn the skills required to make effective use of the library. Snyder (1965) puts it properly when she *writes:*

> If he [the student] can successfully complete the academic program by reading the text, attending lectures, and passing an examination based on text and lectures, there will be little stimulus for him to build a competence in research or using research tools.
>
> Here the responsibility rests with the faculty members.

Clearly the investigative laboratory idea would not permit a student to "complete the academic program by reading the text, attending lectures, and passing an examination. . . ." However, the crucial question is whether the faculty really expects serious library search *before* a laboratory investigation is formulated.

2. Library instruction should be an integral part of the students' class work. Therefore course work should be developed with the idea that it will provide opportunities to practice using the library (Snyder, 1965 and Knapp, 1966). This may seem like an obvious point. Yet the normal situation is the inclusion of library instruction as an afterthought. Instead, faculty members and librarians must work to develop meaningful assignments that include instruction and practice in the use of the library.

3. Library instruction should provide an opportunity for the student to carry out the actual steps of a library search. Phony exercises which ask students obscure questions about where to find a variety of facts are inappropriate busy work and should be avoided.

The general biology course at Earlham College, while not containing an investigative laboratory per se, does suggest a model for the library's role in an investigative laboratory. The Earlham course consists of two 10-week terms dealing with six general areas: (1) populations and ecology; (2) organisms; (3) behavior; (4) cells, genes and energy; (5) development-growth, differentiation and regulation; and (6) biology and society. Beyond the objectives of the course, there are a number of collateral or behavioral objectives which are considered by the staff to be important. These objectives can be broadly summarized as communication and information processing. Improvement in communication is accomplished through the development and practice of oral skills and writing skills. Information processing involves the ability to gather, analyze and synthesize biological information from various sources (e.g., field, laboratory, library, other students, faculty) in order to solve problems.

Each portion of the general biology course is designed specifically as a *modus operandi* for achieving these goals. A sequence of two lectures per week provides subject matter coverage as do the reading assignments. Quizzes, given weekly, provide a check for the faculty and the student of his progress in grasping subject matter. A brief set of readings is used in the weekly discussion groups to provide a focus for practicing the skills of communication and information processing in small group situations. The library component, about which more will be said later, and the laboratory work provide opportunities for attempting the laboratory aspects of information processing and the skills needed for effective written communication.

The library instruction program used in the general biology class is a program that meets the three criteria enumerated above. The faculty impressed upon the students the importance of the ability to use the library. They have done this by stating it in their objectives for the course, by allowing time for library instruction in the course schedule, and by evaluating students' written work (partially on the basis of their information sources). In the final analysis, the staff made it virtually impossible to successfully complete the course without using the library effectively.

The structure of the library instruction program will best show how the student is given an opportunity to practice the actual steps of a library search. The instruction was provided in three stages. The first two occurred as part of a laboratory period early in the term. During the laboratory period, the science librarian talked to the class about certain routine matters (e.g., how to use microfilm readers) and then students were introduced to the "guided exercise," which was the second stage. Briefly, this exercise consisted of a simulated library search in one of three subject areas: ecology, genetics, or animal behavior. The simulation covered not only the search strategy (e.g., when to use a particular reference book), but also showed how to use the various tools. The simulation of search strategy covered such areas as: (1) the use of secondary and tertiary reference sources; (2) the author approach to the card catalog; (3) the subject approach to the card catalog; (4) the use and importance of annual-review-type literature; and (5) the use of serial indexes. The major reference tools explained include the *McGraw-Hill Encyclopedia of Science and Technology*, the card catalog including the serials file, *Science Citation Index*, and *Biological Abstracts*.

The exercise was written in the form of programmed instruction. However, it depended on more than just going through printed frames at one's place of study. It required the student to go to the library and actually carry out a series of steps which encompass an appropriate search strategy. For a more complete description and an evaluation of the guided exercise, see Kirk (in press).

The exercise was exclusively a library assignment and was not related to other activities in the course at that time. However, because it paralleled later work in the course and was designed to meet the needs they would have then, the overall effect was as a series of assignments which gave the student increasing independence to investigate his own problems. At about the time the students were doing the library guided exercise, they were finishing up an ecology laboratory in which the central question was to describe and compare "species composition, diversity, and productivity of trees on two slopes in Sedgwick's Rock Preserve" (a college-owned woodland plot). While students were not expected to use the library to complete the laboratory, many made a somewhat confused attempt to do so. This and several other assignments that might have involved the use of the library, but did not require it, created some motivation to use the library.

The first library exam was the third stage of the library instruction. The students were to answer a question through the use of information found in the library. The faculty's objective was to give a question which required evaluation and synthesis of information rather than a cut-and-paste job. In appended block are the instructions for the exam question along with five sample questions. The faculty evaluated the answers to these questions on the basis of: (1) coherence and logical presentation; (2) writing skills; and (3) literature sources and their evaluation. This does not mean that the staff had developed a precise list of "must" references. Instead, a more general evaluation was undertaken, where we asked such questions as: Were appropriate sources for a paper in biology used? Were primary sources used? Were an adequate number of sources used?

Two weeks after these exams the first experimental laboratory was completed. For the last several years this lab has dealt with bean root growth and the factors which affect it. Students were free to choose their specific areas of study within the limits of available equipment and the techniques required. The students were expected to do their library research, then present to the faculty members of their respective lab sections experimental designs based on their library work. The students had 2 weeks to develop their methods and about 4 weeks to complete the experiments and write-ups. Unlike students in an investigative laboratory, these students were dividing their attention between their bean experiment and other course activities. From that point on, and throughout the second term of the course sequence, it was expected that the library would serve as an important source of the information whenever students had need for information for an assignment. In fact, what was being emphasized was a pattern of self-education which was the overriding goal of Earlham's general biology course.

In all upperclass biology courses it is assumed that students have had this program of library instruction in general biology. Therefore, investigative-type assignments can be made without taking time to make sure students know how to use the library. Some time is provided to deal with specific new reference sources (e.g., *Chemical Abstracts*) but the general skills required for effective library usage are assumed to be part of a student's repertoire of skills. (See following article by Daniel May.)

The role of the library in the general biology course, as well as the success of the specific program of library instruction, has been evaluated and reported elsewhere (Kirk, in press). Here these results can only be summarized. (1) The guided exercise taught the use of the library as well as a conventional lecture-demonstration. (2) Students' opinion of their library instruction was positive. (3) According to the students, the library was appropriately emphasized in the general biology course. (4) There was a strong feeling (92%) among students that the library exams were a valuable educational device. (5) Students felt they learned more through the library exams than through regular objective-type examinations.

TABLE 1. RESULTS OF STUDENT QUESTIONNAIRE ON ATTITUDES TOWARDS THE LIBRARY AND ITS ROLE IN GENERAL BIOLOGY.

	1969-70	1970-71
What type of examinations do you prefer?		
objective hour exams	6%	not used in
short essay hour exams	27%	'70-'71
long open-book essay exams	10%	questionnaire
library exams	46%	
other	11%	
Were library exams		
overemphasized?	30%	32%
appropriately emphasized?	67%	64%
not emphasized enough?	2%	4%
no response	2%	—
Students rated their competence in using the library to obtain information in biology.		
Excellent	31%	21%
Good	47%	54%
Average	17%	25%
Fair	3%	0%
Poor	1%	0%
No response	1%	1%

These evaluations are based on the students who took the general biology course in 1968-69. Since then, additional evaluations have been made. The results of these evaluations are reported below. The items on the questionnaires have been very similar from year to year so it has been possible to compare responses and look for any significant trends. The pertinent sections of the questionnaire for 1969-70 and 1970-71 are included in Table 1. The results are in agreement with the conclusions outlined above.

To convey more clearly the exact way in which the library could ideally relate to the investigative laboratory, the remainder of this paper will be devoted to a detailed look at a student's use of the library in relation to a bean growth laboratory in Earlham's general biology course.

Certainly this program is not an investigative laboratory. However, the type of library use in the Earlham program can and should be adopted as part of the investigative laboratory. It is hoped that this presentation will provide a picture of the nature of the involvement. The search described is that of an actual student. She was a junior, not majoring in any of the sciences, and was taking general biology as part of her science distribution requirement.

She was given seven pages of background and supporting information on "Factors influencing root development in *Phaseolus vulgaris* var. red kidney." This mimeographed handout provided directions on how to become familiar with basic plant structure and function through readings and observational laboratory work. Also included were general comments on types of culturing techniques and other techniques and experimental design problems. The handout concluded with two sample articles on plant growth which were intended to provide samples of how to write up an experiment (Israelstam, 1968 and Pimentel, 1962). She was to read the handout before coming to her laboratory session the following week. At this point in the term she had completed the library guided exercise and had taken one exam on "The Cause of Leaf Coloration in the Fall."

Sometime during the 3-hour laboratory period her instructor expected a generalized experimental design and a list of materials needed. She decided to work on the effect of radiation on bean root growth. During her conversation with the professor, she developed a very general hypothesis that "radiation will have damaging effects on root growth." She decided the dependent variables would be the viability of the seed, age of the seeds, and the effect of radiation on the seeds. The experiment's independent variable would be radiation levels.

The discussion with the professor also raised many questions of which only a few are listed here: Are there other dependent variables? How do you calculate radiation levels? What dosage should be used? How should the experiment be set up? What are the "effects" likely to be? How are the "effects" to be measured? During this conversation she was also told that her radiation would consist of gamma rays from a Cobalt 60 source with a strength of 3 millicurie.

She came to the library after the laboratory period to begin her search in an attempt to answer the questions that had been raised. By using the library skills she had learned in conjunction with other work in the course, she was able to make intelligent use of the literature. She began her search with a basic encyclopedic source (in this case, the McGraw-Hill Encyclopedia of Science and Technology, 1966). The index entry "radiation injury" directed her to two sections of the encyclopedia, volume 3:667-668 and 11:241-250. These two articles provided basic background materials (e.g., conceptual framework for the subject, definition of terms, and range of dosages). The bibliography on page 252 of volume 11 was useful in leading her to more detailed sources.

After exhausting this line of attack, she turned to the card catalog. First, however, she checked the subject heading list which is the basis for the subject entries in the card catalog (U. S. Library of Congress, 1966). She checked the term that was most obvious: Radiation. In the subject heading list she was able to establish the several headings that appeared useful: Radiation—Physiological effects, Radiobiology, and Gamma rays. Her check of the card catalog revealed several titles that potentially would be useful to her project. Careful examination of the titles revealed that *Radiation Biology* (Casarett, 1968) would be the most useful. This title was an excellent source which covered all aspects of radiation biology. There were extensive sections on the basic physics and biology of radiation and then sections on special aspects, of which "Effects of radiation on higher plants and plant communities" was the most useful. The study of this material proved most beneficial for her project. It not only provided more background information but gave her detailed material on specific problems: dosages and how to calculate them, experimental design and techniques. Most importantly, it opened up a new variable—water content of the seed. This eventually became her experiment's independent variable.

By this time she was sufficiently well versed in the problem of gamma radiation effects. It remained for her to determine more precisely how "effects" were to be measured and whether other research might suggest the approach her experiment should take. In addition, a more precise hypothesis or prediction of the results would be useful.

The first and most obvious approach she tried involved the use of the references in Casarett. Three of these references looked especially useful (Gunckel, 1954; Bieble, 1965; and Gordon, 1957). Gordon was the only reference available in the library. This turned out to be quite sufficient for continuing her research since it was one of a series of four articles under the title "Symposium in the Effects of Ionizing Radiation in Plants." The most useful of the four was Gunckel's "The effects of ionizing radiation on plants: morphological effects" (Gunckel, 1957). From the article a number of important pieces of information were drawn which included: (1) Results from one species or variety should not be applied to others. (2) The reference, Quastler, 1952, should be checked. (3) Many responses from gamma radiation are frequently observed in nature but are speeded up or accentuated by the radiation. (4) Chromosonal damage and/or mitotic inhibition in meristem cells may contribute to reduced growth. The article does not help on the question of effects of radiation on seeds.

The pursuit of the references in Gunckel (1957) produced no useful leads.

In many areas of science there are review-type publications which are easily identified by the heading *Annual Review in* or *Advances in*. Students were told in the guided exercise to find the appropriate title early in their search. She did check the subject index in each of the volumes of the *Annual Review of Plant Physiology* from 1964 to 1969. The indexes for volumes 16 (1965) and 19 (1968) both contain entries under gamma radiation or radiation effects.

In "Physiological effects of gibberellins" (Paleg, 1965) a recent work on gamma-irradiated wheat seedlings was mentioned (Haber, 1960). While this reference itself was not useful for methodology, etc., it did provide two references that would have been very useful (Schwartz, 1956; and Sicard, 1959). Unfortunately neither of these references was available in the library.[1] *Biological Abstracts* was consulted for summaries of the articles. Both summaries made the articles look more important. These references were noted and saved for later use in the *Science Citation Index*.

The other article referred to in the index of the *Annual Review* was "Ionizing radiations as research tools," (Haber, 1968). This article makes reference to an article also referred to in Paleg's article (Haber, 1960), and, in addition, to another article by the same author. This latter article did not turn out to be useful. Haber's article also talked about the importance of moisture in intensity of radiation effects.[2] Three references on this aspect were noted. They were not available, but abstracts were sought in *Biological Abstracts*. When located, it was found that they were on x-ray irradiation and were rejected.

The check of the *Annual Review* had led to two useful references, neither of which was available in the library. These two references were checked in the *Science Citation Index* and led to the following new articles:

Schwartz, 1956:			
Haber, A. H.	1964 Am. J. Botany	**51:**	151
Congdon, C. C.	1966 Cancer Res.	**26:**	1211
Vanhuyst, R.	1967 Radiat. Bot.	**7:**	217
Haber, A. H.	1968 Ann. R. Plant	**19:**	463
Haber, A. H.	1968 Radiat. Bot.	**8:**	39
Banerjee, S. K.	1967 I. J. Genet.	**27:**	417
Haber, A. H.	1969 Radiat. Bot.	**9:**	473
Reuther, G.	1969 Radiat. Bot.	**9:**	313
Wangenhe, K. H.	1970 Radiat. Bot.	**10:**	469
Sicard, 1959:			
Stein, O. L.	1964 Radiat. Research	**21:**	212
Campbel, W. F.	1966 Radiat. Bot.	**6:**	535
Haber, A. H.	1968 Radiat. Bot.	**19:**	463

These articles were not related to the question of gamma radiation effect on *Phaseolus vulgaris* seeds and she therefore did not investigate any of them.[3]

The final step was to search *Biological Abstracts*. Beginning with 1970 she checked the terms gamma rays (radiation) and *Phaseolus vulgaris* for useful articles. After finishing the 1970 issue, which located one useful article (Goranov, 1965), she reduced her search to *Phaseolus* sp. and particularly

[1] Again the problem of inadequate library resources has ruined a good bibliographic lead. Admittedly this is a difficult problem with which the library must deal. The solution that seems most reasonable is to choose a subject area in which the investigative laboratory is to be involved and then commit funds to a gradual development of the library in that area. This can be done less expensively through the purchase of microfilm copies of journals and photocopies of individual articles. The limited resources of the Earlham Science Library have not prevented the students from doing an acceptable literature search, even when time limits restrained them from ordering photocopies of articles on interlibrary loan. The investigative laboratory, on the other hand, permits students to proceed at an individual pace, and therefore students do have time to order items on interlibrary loan.

[2] An important step of searching would have been to check important authors (e.g., Haber) in *Biological Abstracts* or *Science Citation Index*.

[3] This sample search was not selected to show a perfect search. Instead, a typical search, if such exists, is demonstrated. Therefore, some steps, such as the use of the *Science Citation Index*, do not produce the results that one would usually expect.

P. *vulgaris*. She continued her search through 1966 and found two references on the effects of water soaking (Heydecker, 1967 and Orphanos, 1968) and one on x-ray and neutron irradiation effects on *P. mungo* (Jana, 1964).

She had done a rather complete search and was ready to finalize her experimental design and sharpen up her hypothesis. If this had been part of an investigative laboratory she might have completed the initial experiments and then conducted additional searches related to new questions raised by her experimental results.

This search took between 5 and 6 hours, including time spent actually reading the material located. This amount of time might be questioned by students if they felt it was unnecessary, tedious busy work. However, our strong impression is that this is not the case. The library exams mentioned earlier, which should involve about 5 hours of library search, actually take about 6-8 hours of search time. Yet students prefer the library exams over an hour factual recall examination. It is clear to the Earlham general biology staff and the Earlham library staff that the experimental laboratory experience and the associated library work were stimulating, educational assignments.

Appendix I

Exam instructions:

This examination is to be written outside the classroom. You should provide an essay-type answer limited to 5 double-spaced, typewritten pages (250 words per page) or 1250 words. Papers in excess of this will not be corrected.

Should you want to include figures, tables, graphs, etc., in your paper, they should be attached to the back of the paper and should not be counted in the total of 5 pages.

The examination is due in the departmental secretary's office no later than 5:00 P.M. Friday, January 31. PLEASE PUT BOTH YOUR NAME AND *LABORATORY INSTRUCTOR'S NAME* IN THE TOP RIGHT HAND CORNER OF YOUR PAPER.

You should budget your time working on this examination approximately as follows: time in library—5 hours; time in organizing—1 hour; time in writing—2 hours.

Please provide at the end of your paper a list of all references used in preparing your answer for this examination, and cite them in standard fashion (see *AIBS Style Manual)* in the context of your essays.

We would emphasize that you are free to talk with anyone while you are preparing to write your answer, but the expectation is that your answer will be yours and yours alone.

PLEASE HAVE RESPECT FOR THE LIBRARY! You are not the only one using the library. We would urge you to be considerate of others. Do not, during the examination, remove any book or materials from the library (whether or not you are the only one using it). Be sure to use your talents in the use of the library.

Sample questions:

1. Discuss the factors that control the distribution of barnacles. Select a single species. Support your discussion with evidence—*not your opinion.*

2. Downtown businessmen are continually concerned with the excrement covering the outside of their buildings. They, of course, have tried many things to remove the producer of the excrement—the Starling—from urban United States. Discuss the ecology of these increasing Starling populations and the problems involved in controlling them.

3. To maintain his agriculture, man has devised many methods. One of the most efficient methods of maintaining agricultural productivity has been to control the diseases and insects that attack his agricultural crops. In many instances, these so-called pesticides have been used without due consideration for the effect of these pesticides on other populations. Discuss the effect of Dieldrin on invertebrate populations using your ecological knowledge as a basis for your discussion.

4. Discuss five examples of possible exceptions to the rule that there is no such thing as sympatric speciation. Define your terms and take a position on whether or not you support the rule.

5. Document three examples of homology and three examples of analogy in the evolution of plants or animals. Is phylogenic classification the best way to do it, or would a more ecologically oriented taxonomy be better? What are the advantages of each?

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AN INVESTIGATIVE LABORATORY IN CELL PHYSIOLOGY

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As is the case elsewhere, the objectives of the investigative laboratory in cell physiology at Earlham College are to involve students with and to improve their competence in all facets of the process of experimental investigation. These include attaining familiarity with relevant literature; identifying and defining problems for investigation; formulating testable hypotheses; designing experiments to test hypotheses; executing experiments; interpreting experimental results; and communicating procedures, results, and conclusions. It is important not only that students develop competence in these areas, but that they also perceive that they have developed such competence Accordingly, implicit in the objectives is our desire for students to develop confidence in their abilities to function as competent investigators.

Operationally, competence and confidence are best obtained by doing; simply having the students become involved in the process of investigation is undoubtedly our most effective "method." However, contact with the instructor—a more experienced investigator—is also important; frequent interaction with and feedback and support from the instructor, at all stages of the investigation, can greatly facilitate the attainment of the objectives. Furthermore, confidence in his investigative abilities seems to come more readily when the student brings his investigation to a successful conclusion. The approach described in this article was designed with these considerations in mind.

Format of the Laboratory

The first 3 weeks of the 10-week term constitute an introduction to three areas (mitochondrial metabolism, enzyme activity, active transport) of experimental investigation. The students spend a week in each of the areas, working through an exercise (I refuse to call it an experiment) directed in admittedly "cookbook" fashion by a mimeographed handout and supervised by the instructor. The purpose of this introductory phase is to instruct the students in techniques and familiarize them with procedures so that they will be better able to design their investigation.

The fourth week and part of the fifth are spent in the library and in the instructor's office. After choosing one of the three areas for investigation, the students, working in self-selected groups of one to three, research their topic in the library, gradually narrowing it down (often aided by frequent brief consultations with the instructor) until they have a problem of a scope suitable for investigation in the time allotted. (By the time they take this course, the students have become rather adept at library search strategy and the use of *Biological Abstracts* and *Science Citation Index*—see the preceding article by Kirk.)

By the middle of the fifth week, each group submits a "pre-lab"—in effect, the introduction and methods sections of its paper. This includes a brief review of relevant previous work; an hypothesis or a statement of a problem, with justification; and a detailed statement of experimental design. The latter is probably the point where involvement by the instructor is most crucial and most fruitful. Designing experiments capable of answering questions which test hypotheses are often a difficult undertaking. The methods portion of the pre-lab frequently needs some reworking, and the instructor must help the student see how to devise an adequate control, determine the number of replications necessary, decide on appropriate concentrations, etc.

Equipped with a solid experimental design, the groups begin laboratory work on their projects in the fifth or sixth week. At least 5 full weeks are thus available for laboratory work on the project. The amount of student-instructor interaction during this phase is, of course, quite variable, some students consulting the instructor every day or two, others very infrequently. However, one further occasion for feedback is programmed into the course. During the eighth week each group submits an informal progress report, consisting of its results to date and an interpretation of them in light of the hypothesis. This report also contains a pre-lab for subsequent experiments, since some groups find it necessary by this time to further refine, modify, or extend their hypotheses.

A formal report, in the usual style for a journal article, is submitted by each group at the end of the term. Most of the reports are exemplary, both in their form and in the thought that goes into their preparation. However, on infrequent occasions there is, even at this stage, a marked need for revision. In these instances, the student is given an "Incomplete" in the course pending the submission of an acceptable report.

In summary, the format is designed to involve students sequentially in the various phases of experimental investigation. In addition to numerous informal opportunities, formal occasion of student-instructor interaction are built into the program. Examples and additional commentary are provided below.

Areas of Investigation

The three investigational areas have been standbys of cell physiology laboratories for a long time, yet they are readily adaptable to an investigative laboratory approach. They are listed below, along with brief outlines of basic procedures.

Mitochondrial metabolism. Mitochondria are isolated from rat liver by a standard procedure of homogenization in a sucrose-EDTA solution and differential centrifugation.

The respiratory activity is then determined by measuring oxygen consumption in a Warburg manometric apparatus. The main compartment of the flask contains pyruvate as substrate, phosphate buffer, NAD, mitochondria, and a hexokinase ATP-glucose mixture as an ADP-regenerating system. A piece of filter paper soaked with potassium hydroxide solution is placed in the center well to absorb carbon dioxide. While not included as part of our introductory exercise, it is pointed out that analysis for inorganic phosphate could be done to follow the course of oxidative phosphorylation.

Enzyme activity. Good success has been obtained with wheat germ acid phosphatase and with yeast invertase, both of which can be readily assayed colorimetrically; phosphatase activity is assayed using the Fiske-Subba Row procedure, and invertase by the dinitrosalicylic acid method. In my experience, invertase has given results which are more reproducible, whereas the phosphatase allows a greater range of possibilities for studying substrates or inhibitors.

Active transport. A bag is made from the skin of a frog's leg, into which is pipetted a dilute Ringer solution. The bag is tied and immersed in a test tube containing the same solution. This assembly is placed uncovered on a wrist-action shaker and shaken for several hours, after which aliquots are removed from the bag and the surrounding medium. After appropriate dilution, sodium ion concentrations are determined by flame photometry.

Each of these procedures can lend itself to a wide range of modification, and is thus amenable to the design of experiments to test a variety of hypotheses. The procedures are given here and are presented to the students during the introductory phase of the laboratory, not to pose as experiments in themselves or to closely specify subsequent studies, but rather to suggest approaches which can be fruitfully employed in the investigation of interesting cellular phenomena. Examples of a few such investigations are given in the following section.

Examples of Projects

Each of the three general procedures described in the preceding may be employed, with modification, to investigate a wide range of interesting problems. For example, studies in mitochondrial metabolism which may be done include the determination of P:O ratios in the presence of various substrates, inhibitors, or artificial electron donors or acceptors; comparisons of respiratory activity of mitochondria isolated from different tissues, or from different developmental stages of the same tissue; studies of respiratory control through the use of uncouplers of oxidative phosphorylation and enzymes with ATPase or kinase activity; or determining the relative effects on Krebs Cycle and electron transport activities of mitochondrial disruption.

Enzyme studies, using the enzymes referred to above or others, could entail determining K_m values with different substrates, studying the effect of limited proteolysis of the enzyme on its activity, ascertaining the extent to which the substrate protects the enzyme from denaturation, determining whether a particular enzyme is allosteric, or doing kinetic studies to determine the types of inhibition shown by certain inhibitors.

Students studying active transport might carry out investigations to determine the relationship between sodium ion concentration and its rate of transport; to identify the nature of the metabolic energy source for the transport process; to determine whether ions other than sodium are transported and if so, whether it is possible to dissociate the sodium pump from the other pump(s) or investigate the action of pharmacological agents on active transport.

Obviously, there is quite a range of possibilities for interesting and feasible studies. Below are listed the titles of a few investigations which have actually been carried out—in many cases with results of considerable interest—during the past 2 years. (In a few cases, the titles have been modified to make them more descriptive of the study.)

The Effects of Detergent and Osmotic Disruption on Mitochondrial Respiration.
Respiratory Control in Rat Liver Mitochondria.
Glycolysis and Respiration in Yeast.
An Investigation of Ethanol Metabolism in Rat Liver Mitochondria.
Effects of Freezing and Thawing on the Relative Rates of Oxidation of Pyruvate and Succinate in Rat Liver Mitochondria.
On the Energy Source for Inorganic Phosphate Transport by Rat Liver Mitochondria.
Reactivation of Heat-inactivated Acid Phosphatase.
On the Number of Qualitatively Different Active Sites in a Crude Preparation of Wheat Germ Acid Phosphatase.
Effects of Manganese Ion on Beef Liver Glutamate Dehydrogenase.
Allosteric Nature of Brain Monoamine Oxidase.
Localization of the Sodium Pump in Isolated Frog Skin.
Active Transport of Glucose Across the Frog Skin.
On the Necessity of Oxidative Phosphorylation for Active Sodium Ion Transport.
A Comparison of the Rates of Oxygen Consumption by Sodium Ion-transporting and Non-transporting Frog Skin.
Effects of Phenobarbital on Active Sodium Ion Transport by Frog Skin.
Active Transport of Sodium Ion by Frog Skin From Which the Epidermal Layer Has Been Removed.

Student Reactions

While recognizing that the evaluative comments an instructor gets about his course are generally skewed toward favorability, I nevertheless feel that the investigative laboratory component of the course has been well received by the students. This judgment is based on oral comments from students in the course reflecting both their reactions and what they believed were the feelings of their classmates, on comments from other students and faculty members concerning remarks they had heard about the laboratory, and on anonymous written course evaluations submitted by students at the end of the course.

Nearly all of the students felt that it was a good idea to be introduced to the three investigational areas from which to choose their projects. They appreciated having a starting point, feeling that the guidance provided in this way saved them a lot of time that otherwise would have been largely wasted in attempting to choose an area in which to do a project which was both feasible and interesting. All were glad to have had complete freedom in choosing a problem within the area in which they decided to work. Nevertheless, many approved of my decision to let students having a strong desire to do so work on projects in other areas.

Without exception, students felt that there were ample opportunities to do interesting investigations within their project areas. They rated their project in particular and the investigative laboratory experience in general, much more interesting and enjoyable than their laboratory experiences in other courses.

The pre-lab was considered a very effective device for insuring that students focus early on what they are going to do, get into the literature, and plan carefully. Also receiving favorable comment was the interim progress report, both because of the incentive it gave to complete the work as early as possible, and because it was an opportunity to receive helpful criticism and suggestions from the instructor.

In terms of the objectives stated in the introductory section, most of the students felt that their experience had been reasonably successful in helping them in improving their abilities to identify problems, formulate hypotheses, and design experiments. However, they felt they had made less progress in the subsequent phases of the investigative process. Whereas a majority reported that their ability to function independently had improved, only a few claimed to have achieved confidence in the use of investigative skills.

Perhaps one of the most cogent comments on the investigative experience, the essence of which was expressed by several students, was this:

> It revealed to me what scientific research can really be like—a lot of hard work before appreciable results are obtained. I also came to see it as a challenge in which you become very self-motivated to dig into a problem to see how far you can go and how much you can learn. It's sort of like reaching out to find where your limits are and then pushing to expand them. I found out that one must be flexible in his thinking, not hesitating to use imagination, and above all that persistence is a prerequisite for results.

Further Commentary

As I see it, the most fundamental difference between the approach used here and that used in most other investigative laboratory programs is the absence, in my approach, of complete freedom for the student in choosing his area of investigation. However, I feel that this restriction is more than compensated for by some distinct advantages:

1. Since the student is working in an area where we are familiar with the experimental system and have eliminated some of the major bugs, chances are good that the investigation will be successful (as most of them have been). I feel this to be an important point, too frequently neglected in other treatments of the investigative laboratory. A good opportunity for success and the positive reinforcement that comes with it are very desirable features of an investigative laboratory, especially for the development of confidence. This is particularly important for students who are involved in their first investigative situation. (I realize that there is educational value in failure, too, and that it would be a misrepresentation to portray all scientific endeavors as successful. Nevertheless, I feel that these goals are less important than the favorable attitudes toward investigation which will more likely come with success, so I am willing to defer them until later in the student's career.)

2. The experimental areas used here afford opportunities for many interesting and conceptually rather sophisticated hypotheses which are well based in the literature and are relatively amenable to experimental investigation.

3. A preliminary directed exercise does a much better job than simple reading would in allowing students to gain a working familiarity with a procedure and its possible applications, thus facilitating the design of feasible and meaningful experiments.

4. Many students are paralyzed for a time when given complete freedom; the availability of a starting point and guidelines for an investigation provides some helpful focus.

Students having a strong desire to carry out a project in a different area are allowed to do so if they can make a good case for its feasibility in terms of both available equipment and likelihood of success. One example is a project done last year by two students who, while interested in metabolism yet opposed to killing rats, investigated the effects of inhibitors on fermentation in yeast. Furthermore, they tried to develop some of their procedures for use as another investigative area. While only partially successful, their project is being continued by another student this year; hopefully it will be available next year as a fourth investigative option.

Some brief comments on two other features of our approach:

1. The expectation of a detailed experimental design in the pre-lab forces students to think through their experiments in advance and plan carefully, so that their decisions are made before going into the laboratory, rather than on a more-or-less *ad hoc* basis in the laboratory.

2. The interim progress report affords an important opportunity for feedback and correction; it helps avoid that uncomfortable situation in which the final report is the instructor's first as well as last look at the student's work.

Finally, repeating an opinion stated earlier, *involvement* is probably the most important ingredient for the attainment of the goals of the investigative laboratory. To the extent that this is true, probably any investigative experience, regardless of format, will go a long way toward achieving the objectives.

Vital Statistics

The enrollment in cell physiology is generally 30-35. Most of the students are juniors, but there are usually a couple of sophomores and six or eight seniors. Backgrounds vary widely; except for general biology, introductory chemistry, and one term of organic chemistry (which are prerequisites waived only infrequently), students may have had from zero to as many as eight or ten other biology courses, and from no other chemistry up to advanced organic, kinetics, or thermodynamics.

The course, which is given once a year in a 10-week term, consists of the laboratory component described here and a discussion-reading-writing-lecture component. Students take three courses a term, so cell physiology constitutes about a third of an average course load. The time spent per week in connection with the investigative project—in laboratory and library—averages about 10-12 hours.

The entire cell physiology course, of which the laboratory is one part, constitutes about half the teaching load for one faculty member during the term in which it is given. The faculty member is assisted by an upperclassman who sets up equipment, makes solutions, and sometimes helps instruct in the use of equipment. Since the time the faculty member spends in connection with the lab is largely fragmented into frequent and brief periods of consultation with students, reading pre-labs and progress reports, and so on, his expenditure is difficult to estimate—my guess is that about 8-10 hours per week are required for the laboratory.

Envoi

The investigative laboratory represents a major step along the route from science appreciation to science in the biology curriculum. I am pleased to have traveled this far, I can't imagine returning to my point of departure, and I look forward to the journey ahead.

STUDENT-DESIGNED EXPERIMENTAL STUDIES ON THE ENVIRONMENTAL EFFECTS OF PESTICIDES

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During the past semester at Middlesex County College students in my laboratory sections in introductory biology and microbiology worked in project groups to explore various aspects of pesticide effect on soil organisms. A basic aim of these student-originated studies was to encourage students to develop their own capacities for analysis and solution of a problem. Corollary aims were to enable them to appreciate the total processes of experimental research and to gain some useful knowledge in an area of investigation in which the literature is somewhat sparse.

The format used in the development of the studies began with speculative discussions on the redistributive roles of soil organisms in recycling life-essential elements and on what modifications in soil populations could result from pesticide use. Emphasis then shifted to practical (and basically, non-complex) laboratory investigations that might demonstrate the range of pesticidal effects on these "innocent bystander" organisms. Students were encouraged to work in groups to design laboratory studies that would yield information on specific facets of the problem. The inclusion of adequate control groups in the project designs came to be recognized as an indispensable factor in meaningful findings.

Subsequently the laboratory sections analyzed the designed protocols suggesting points and areas for refinement. A materials list made from the modified plans was submitted to our laboratory technician one week prior to the beginning of experimental work. Students provided their own samples of commercial pesticides. A listing of project categories and/or titles follows:

- Effect of Kelthone dilutions on *P. sativum* germination.
- Effect of Kelthone dilutions on the survival of *L. terrestris*.
- Determination of soil microbe survival versus Chlordane dilutions in petri plate assay.
- Effect of Dieldrin on growth of pea seedlings.
- DDT 225 effect on *A. aerogenes* using replica plating.
- Effect of Lindane dilutions on soil microbial populations using petri plate assay
- Filter disc—petri plate assays of the effects of Chlordane and Lindane dilutions on selected bacteria.

The experimental work continued through two to four laboratory sessions after which the groups submitted written reports for group discussion.

These studies stressing the recognition of aspects of a current environmental problem and the capacity of students in laboratory sections to find some answers had evident values.

They encouraged the greater involvement and added interest on the part of most students; they provided students with an opportunity to directly experience the total processes involved in scientific problem-solving. As noted by J. W. Thornton in **CUEBS NEWS**, February, 1971, it is "discouraging how few introductory college biology courses provide an opportunity to receive experience in using these processes." And, of course, the worth of the findings (however fragmentary) on pesticide activity against soil organisms was itself sufficient gain for the effort made.

A paper given at the Second Annual Biology Symposium, Ulster Community College, Stone Ridge, New York, April 30-May 1, 1971.

HOW DO STUDENTS VIEW THE ACTIVITY OF INVESTIGATION?

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As biologists with a tradition of research, we clearly perceive the importance of the laboratory in uncovering new knowledge, testing ideas, and formulating new understandings. However, it is a rare undergraduate who shares this perception of the laboratory. For the undergraduate teaching laboratory to survive the 70's, in the face of mounting financial difficulties and increasing student pressures, the laboratory must become to our students that which it is to us—a place for investigation.

An important step is observing how students view the activity of investigation. As a staff biologist with **CUEBS** during the academic year of 1970-71, I set out to record the views of students and their teachers on investigation. My study took me to five campuses, where I conducted interviews with nearly 50 undergraduates; many of these interviews were recorded on audio-tape. I have added to this large store of comments the recollections of 25 teachers interested in sharing the art of investigation with their students .

In the initial stages of investigation, there is a good deal of uncertainty as to what lies in store. As one teacher put it,

> By and large, college students want and enjoy the challenge of the unknown that I-labs provide. It is a rare student, however, who can be thrust into such a lab and be expected immediately to "start investigating."

Students perceive this fact quite clearly. This is reflected in their comments to questions about first impressions of the investigative laboratory. Some examples are:

> "I really did not know what was going on at first."
> "It was a shock."
> "It was really different."
> "I hadn't expected this type of laboratory."

Without exception, the successful teacher of investigation is aware of this initial sense of uncertainty and proceeds to build a foundation for investigation. The roots of uncertainty are quite individualistic. However, the more common sources of concern can be traced to difficulties of selecting a problem that is approachable through experimentation. Comments by teachers pinpoint this common difficulty.

> Students unaware of the subject tend to choose enormous problems—those far beyond the resources available to them. Most no longer try to cure cancer in three months, but their proposals are usually far too grandiose. Actually, it is hard to find a problem too simple to be worthy if it is explored to its limits.

> . . . the questions they ask are frequently much too broadly defined and need to be narrowed considerably.

In relating his own experience with this difficulty, one student said, "Choosing my problem was a snap; but stating it in the form of an experimental design, that was a different story."

The origins of problems for investigation are easily revealed through inquiry. Teachers and students cite the following sources:

> Some (students) come into the course "knowing" just what they want to investigate. Some have ideas or questions generated as a result of the formal laboratory studies. Others become interested in an area after examining "bound" copies of students' investigations carried out in previous semesters.

> Comments made in lecture got me started on a problem.

> My problem came out of a discussion in my fraternity about drinking alcohol.

> I happened to choose my project on the basis of outside reading.

> Recent surgery performed on my father stimulated my interest on the effects of cholesterol.

Since the selection and formulation of a problem is critical, most teachers allow several weeks for this process to take place. It is during this 3-4-week period that the student is developing his role as an investigator. At this time the teacher must provide a carefully planned mix of activities for the student including use of the library, laboratory experience with potentially useful techniques, group discussions, and individual conferences.

Closer examination of each planned activity reveals that while most students find initial planned activities helpful, few students are in agreement as to which activity is most helpful. Some students find that a search of the literature provides them with clues to the eventual formulation of a problem. Other students become interested in investigations that stem from difficulties with laboratory techniques. Still others cite group discussion and individual conferences with the teacher as the source of ideas for investigating.

Once individual investigations are underway, new problems begin to emerge. As might be expected, difficulties are encountered in obtaining materials and supplies for the investigation. On the whole, however, such difficulties are viewed as minor and alterations in experimental design are accepted as the outcome of "dealing with the real world."

As the results of investigation begin to take shape, a climate of excitement starts to build. This occurs in spite of the routine difficulties often experienced during the course of any investigative activity. In reporting the outcome of an investigation in marine biology, three teachers made the following observation:

> Excitement in the exercise ran high and continued high, despite rains, rough water, long hours, and the frustrating

difficulties of trying to follow and record the activities of a partially submerged population of purplish black animals at night. This was at least partly because information new to both students and faculty was continually coming in.

Apparently, the knowledge that students are breaking new ground during an investigation provides a continuing source of stimulation to these neophyte investigators.

Throughout the investigation students encounter questions that require assistance from their teachers. As the investigation progresses, it is apparent that the traditional role of student-teacher is transformed to a relationship between colleagues. As one student put it:

> The advice given us was not just the answers to our questions; but advice that pointed us in the direction of finding answers to our own questions. For instance, I was having problems in getting my algae to grow. Instead of being told to try this or that, my teacher suggested several papers that I might find helpful. Sure enough, I found answers to my own questions. This approach to learning I feel was most valuable—because I found out on my own.

A natural outgrowth of some investigations is the quest for assistance from those outside the context of the course. Several examples of this were cited by one teacher:

> Several students, interested in the detection of coliform bacteria, contacted the health department laboratories. The staff willingly worked with these students and appraised us of their performance. One student sought out the plant physiologist on our staff for assistance. Another student called on a graduate student doing work in his area of investigation. A small number of medical technology students carried out studies in cooperation with the staff of the medical school, and in some cases, hospital laboratories. A psychology major obtained advice and guidance from a faculty member in that department.

Most investigative laboratories conclude with either a written or oral report of the investigation conducted by each student or team of students. It is the overwhelming consensus of students that such an opportunity should be provided. In fact, in one case where this opportunity was not provided a student commented:

> I was quite disappointed that I did not get an opportunity to share my investigation with my colleagues or to hear about their work. I had worked hard on my investigation, and I am sure that others did, and I would have liked to have told others what I had learned.

The following comments are typical of a summary of the benefits gained from the investigative experience:

> The investigative approach decreases cutthroat competition for grades, increases cooperation between students, and improves student-faculty rapport.

> As almost any course taken by freshmen, this one seems to aid some in making a career choice. Students seem to think the course was particularly helpful in this regard because it gave them insight into what biologists actually do in their professional work. For example, one student commented: "I think the course was an excellent one, for it forced me to think about the process of science and taught me how to use the scientific approach in trying to answer questions. This may cause me to change my major."

> Some students also believe that the course may have been influential in changing their general life style from one in which they blindly accepted what authorities told them to one in which they feel a need to look for evidence and investigate problems on their own.

> I found the principal value of the investigative laboratory to lie in the experience of feeling responsible for a project in which *I* was personally involved.

> The things we learned were not just about biology, but about ourselves.

> When asked by some of my friends—"Should I take this course?" I tell them that it was a very good experience for me and I recommend it very highly.

In summary, if you wish to share the vision of a laboratory as a place where others become "eager to learn," then the investigative laboratory is a good bet.

NEW ENVIRONMENTAL BIBLIOGRAPHY ISSUED

Publication of what is believed to be the most comprehensive reference work to date on books, journals, articles, and other literature dealing with the environment is announced by the Commission on Science Education of the American Association for the Advancement of Science. The 96-page compendium is entitled *Science for Society—A Bibliography*. Almost 4,000 references, many annotated, are included. All aspects of the interrelations of man, society, environment, science, and technology are covered; titles are classified and indexed in major and minor categories to help the user find materials on specific subjects.

The bibliography is a second and much expanded edition of a publication bearing the same title and issued a year ago. Dr. John A. Moore, Professor of Biology, University of California, Riverside, and Chairman of the Commission, has again served as editor of the new edition.

Support furnished by the National Science Foundation, E. I. du Pont de Nemours & Company, Xerox Corporation, and the AAAS itself makes it possible to offer the bibliography at the price of $1.00 per copy, or 75¢ each for ten or more copies. Orders, accompanied by payment, should be addressed to the Education Department, AAAS, 1515 Massachusetts Avenue, N.W., Washington, D.C. 20005.

GRADING PRACTICES: A CURRENT BIBLIOGRAPHY

Lilyan S. Khan
Administrative Secretary to the Commission on Academic Affairs
American Council on Education

This brief bibliography lists 42 items, most of them released in 1969 or later, pertaining to grading practices and their reform, particularly "Pass-Fail." This is an extension of Paul G. Tamminen's "A Guide to Resources for Undergraduate Academic Reform," published as an ACE *Special Report*, June 30, 1970. **CUEBS News** is pleased to bring this to its readers, many of whom have requested information on grading practices.

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Viewpoints!

Another Look at the Core Curriculum

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CUEBS Staff Biologist

The concept of the core curriculum is an outgrowth of the great increase in biological information following World War II. As this information accumulated, particularly at the molecular and cellular levels, the distinction between subdisciplines and even between biology and the supporting sciences, became progressively blurred. It soon became clear that traditional courses and curricula could not adequately reflect the status of the discipline. The inception of the core idea provided a vehicle for curricular reform which embraced the new information on the molecular and cellular levels, and accelerated a redefinition of biology along lines of greater integration. New ways of packaging biological information according to levels of biological complexity (molecular biology, cellular biology, environmental biology, etc.), suggested to many biologists that a minimum amount of information at each level was necessary in order for a student to be well educated in biology. It was this assumption that stimulated the study resulting in **CUEBS** Publication Number 18, *Content of Core Curriculum in Biology*. This idea received such widespread acceptance among biologists that today the core curriculum is almost a universal phenomenon among biology departments in the United States.

CUEBS Publication No. 18 focused entirely on the subject matter content of the biology core in four selected institutions. Although the subject matter is a very important aspect of any core program, there are other features that are just as important when considering its effectiveness. In view of this it might be useful to suggest a functional model of a core program.

Origin. A core program may be developed by a department or a committee by compiling a list of concepts and topics that reflect the current status of the discipline. These are then integrated for delivery in a manner that is compatible with the academic organization of the host institution. Acceptance of a core program implies agreement that these are foundation experiences in which concepts, attitudes, and skills are learned that will be directly useful in all other biological learning activities.

Revision. Since the core is designed to reflect the current status of the discipline of biology, it obviously must undergo constant evaluation and revision. As the product of a group rather than a single individual, the core program can be looked upon as the property of the house, as compared with a specialty course, and thus it lends itself more readily to periodic review and revision. As the result, a core has the potential for helping a department to avoid obsolescence.

Presentation. The core program can provide the student with an opportunity to experience a body of integrated biological information, presented in a manner that emphasizes the unification of biological subject matter. This implies a presentation that concentrates on broad concepts and unifying themes as they pertain to all levels of biological complexity. Where more than one instructor is involved in the core program, in order to avoid duplication and to insure that the different segments are complementary, each must be intimately aware of what the others are doing in their portions of the program.

Diversity. As an amalgamation of topics and concepts representative of the discipline, a core program provides a wide variety of student experiences. Consequently he may, more knowledgeably, choose an area for specialization, or he may change his mind about an area he had decided upon before entering the core. The connotation "core" suggests that there are other aspects of the biology program. These foundation experiences will provide the student with a sound judgmental basis for assessing his needs in the remainder of his biology program.

Methodology in Biology. Few biologists will dispute the contention that the essential minimum body of information comprising a core program should include an introduction to the processes by which biological information is acquired. With regard to the assimilation of biological information and to patterns of thinking that will serve the learner in all aspects of his life, this is probably the most important part of the program.

Each student of biology must assimilate his biological information into his own cerebral ecology if it is to have any personal significance for him. If the assimilated knowledge is to bear any resemblance to the original information the student must be aware of the parameters of the latter, its strengths, weaknesses and uncertainties. The core program can facilitate this awareness by providing the student with opportunities to participate in the investigatory process.

Just as the content of a core program should be under constant review and revision, so the concept itself should be periodically reassessed. Since the release of **CUEBS** Publication No. 18 a great many core programs have been observed. Two things are becoming increasingly apparent: (1) There is little agreement as to how the essential minimum body of biological information should be delimited and (2) In many institutions the core curriculum has come to mean simply those courses that are required of all majors.

The first observation should come as no surprise when one considers the many different points of view held by biologists. This may, in fact, constitute evidence that core curriculum, in the abstract, is a meaningless phrase. Perhaps a more realistic definition of core curriculum is "the essential minimum body of biological experiences *as identified by a specific group of biologists.*" The latter describes the situation as it is, and has the advantage of recognizing diversity among

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biology departments. Sameness among biology programs is no more desirable than sameness among institutions of higher education or individuals.

The second observation is probably the result of two interrelated factors. First, the extensive exposure which the core concept received in **CUEBS** Publication No. 18, **CUEBS News, BioScience,** curriculum conferences, etc., may have generated a degree of "bandwagon effect." Some departments have brought together a block of pre-existing courses and with little attempt at coordination or integration offered them as core programs. Second, it is very difficult and time consuming to maintain a highly integrated and coordinated core. Staff members frequently do not have, or will not take the time necessary for such programs. The result is likely to be duplication of effort, loss of continuity, and lowered effectiveness as related to expenditure of student and staff time.

One of the greatest dangers of any core program is the potential rigidity inherent in the concept. The choice of content is, at best, arbitrary and there is always the temptation to insure that coverage is sufficient and that no area of biology is neglected. The result can be a core that constitutes the entire undergraduate program. This type of program inspired one biologist to remark recently, "We don't have a core. We have the whole apple."

Another factor that has resulted in problems in core planning is the assumption that a certain body of factual information must be mastered before the student can experience the unsolved problems in biology. Nothing can do more to dull the interest and curiosity of students than endless memorization of background information and laboratory activities which demonstrate what they already know. The unanswered questions in biology and the problems associated with their answers can be powerful agents of motivation. When students are "turned on," background facts become meaningful and useful tools. Therefore, it seems good pedagogy to design the core program so that a primary focus is on the unknowns of biology.

At a time when biological information is expanding exponentially and obsolescence is a perennial threat, it may be presumptuous to identify any specific body of information as an "essential minimum" for all students of biology. In a world in which the only stability is the stability in change, a given body of information may be out of date even before the student graduates. Mastery of subject matter as the only goal of biological education is thus of questionable validity. A goal which appears to be on firmer ground is helping the student become more independent in learning and using biological information. This entails providing him with experiences that demonstrate the changing aspects of the subject and letting him experience the processes by which biological information is acquired. A reassessment of the core concept in these terms will result in a different view of what is most important for all students of biology. It will shift the current emphasis on coverage of subject matter to one of concern for the growth of the individual. The outcome will be quite different types of teaching and learning.

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Free upon request from CUEBS, 3900 Wisconsin Ave., N.W., Washington, D. C. 20016

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